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DESIGN, DEVELOPMENT, TEST, AND EVALUATION OF A LEVEL C INTERPLANT SHIPMENT PALLET FOR 60 MM M722 WHITE PHOSPHORUS FILLED BODY ASSEMBLIES

Yuen H. Lam

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US ARMY
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Armament Engineering Directorate

Picatinny Arsenal, New Jersey

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13. ABSTRACT (Maximum 200 words)

This report details the engineering design, development, test, and evaluation program to qualify a wooden pallet assembly (drawing 12937963) that is needed for interplant and storage of 60 mm M722 white phosphorus filled body assemblies. The final pallet design met the U.S. Department of Defense standard, MIL-STD-1905, as well as the performance oriented packaging (POP) identification, 49 Code of Federal Register, Parts 107-179, required by the U.S. Department of Transportation and United Nations. The data gathered is recommended for use as reference for other similar shipment and storage requirements.

14. SUBJECT TERMS

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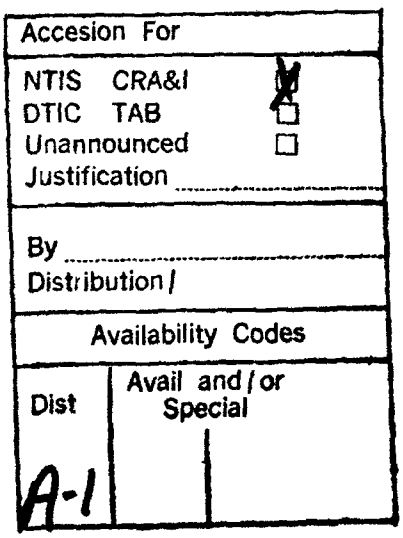


FIGURES

INTRODUCTION

Currently, in order to manufacture 60 mm M722 smoke mortar cartridges, two ammunition plants are used as follows: Pine Bluff Arsenal (PBA) fills the body assembly with white phosphorus (WP) then ships the filled units to the Milan Army Ammunition Plant (MAAP) for the final load, assemble, and pack (LAP) operations. This body assembly is approximately 7-3/16 in. long with a 2-3/8 in. maximum diameter at its center area. It has a filled weight of 2.91 lb (fig. 1).

In order to move the loaded body assemblies from PBA to MAAP, a task was given to the Packaging Division of the U.S. Army Armament Research, Development, and Engineering Center (ARDEC) to design an interplant shipping container that would do the job. To this end, a wood container with top and bottom assemblies that were supported by a standard 40 in. x 48 in., 4 way entry, wood pallet (per MIL-P-15011) was selected to pack 195 body assemblies in a 13 x 15 pattern. This 13 x 15 arrangement was created by a 3/8-in. thick plywood separator interlocked into a 2-1/2 x 2-1/2 in. egg crate pattern. The wood materials were used because of their low cost, ease in fabrication, and their resistance to impact. The body separators were designed to function as isolators for each body assembly to avoid possible damage created by collision among body assemblies during storage and shipment. The original unitized package was held together by four steel straps, two longitudinal and two transverse, to reinforce the palletized load and maintain its integrity. Its gross weight was approximately 820 lb, and the pallet was designed to be reusable.

Concurrently, the technical data required for the task was obtained. The most significant findings were:

- Prior to Oct 91, the hazard classification proper shipping name for a WP filled body assembly was "Flammable Solid" subordinated to packaging group II for shipment within the Continental United States (CONUS). However, beginning on 1 Oct 91, the U.S. Department of Transportation (DOT) adopted the "United Nations Recommendations on the Transportation of Dangerous Goods." Now, according to the DOT regulations, the WP filled projectile body carries the proper shipping name of "White Phosphorus" and belongs to the packaging group I, the category used to ship the most hazardous materials.

- The noted change significantly increased the difficulty of establishing the package design because one of the qualifying tests for packaging group I was to drop the large and heavy "wooden container" in five different orientations from a height of 5.9 ft; whereas, for packaging group II, the drop height was 3.9 ft.

- Furthermore, it was discovered that neither, 5.9-ft nor 3.9-ft drops were previously done under the latest DOT regulations for group I or II packaging.

In April 1991, the Packaging Division completed its unit pack design and forwarded the drawings to PBA for review and fabrication of the required test units. PBA proposed two major changes to the design sent to them. One was to use commercial fiberboard materials in place of the plywood to make the egg crate separator, and the other was to increase the number of body assemblies from 195 to 238 units by creating a 14 x 17 pattern. Consequently, the gross weight became 940 lb approximately, an increase of 120 lb. Engineering consensus at the time was that the corrugated fiberboard egg crate separator would do the job at lower overall cost than the plywood, and the increase in number of units per pallet load would further reduce the cost per unit per pallet load. What remained to be determined was whether the revised pallet load design was robust enough to withstand the qualifying tests. In this light, this report discusses the tests conducted, the problems encountered, and the solutions implemented to correct the problems.

DISCUSSION

General Information

Item Tested: Level C CONUS interplant shipment pallet (drawing 12937963) for 60 mm M722 WP body assemblies (drawing 15-12-344)

Quantity: 208 body assemblies per pallet (final version)

DOT Designations:

- Hazard classifications:

  1. DOT hazard class: 4.2 (substances liable to spontaneous combustion)

  2. DOD hazard class/division (div)/storage compatibility group (SCG): 1.3H

- Proper shipping name (PSN): Phosphorus, white

- Identification Number: UN 1381

- DOT container marking: Phosphorus, white
  UN 1381

- Packaging group: I

United Nations (UN) Designations:

- Proper shipping name: Phosphorus, white
- Serial Number: 1381
- Packaging group: I

Test Criteria:

- MIL-STD-1905
- MIL-STD-1904
- Code of Federal Regulations, title 49, parts 107-179

Test Time Period: October 1991 to February 1992

Test Location: Building 60, Environmental Test Laboratory, ARDEC, Picatinny Arsenal, NJ 07806-5000

Test Personnel:

- Packaging Division Engineering: Y. Lam and D. Kirshteyn
- Environmental Test Laboratory: V. Serban, J. Goble, and A. Huss

Test Results

Before tests were started, the following plan was agreed upon: Two unitized pallet loads would be given the test designations, test samples 1 and 2. If another test sample unit had to be made up, one of the empty pallet boxes would be used and a set of new egg crate separators would be installed. The loaded body assemblies would not be serialized or identified with a specific pallet box assembly. In consideration of this test procedure, the noted test standards used, the observations made at the time, comments, and actions were:

Secured Cargo Vibration Test

Test samples 1 and 2 were tested to evaluate the pallet's construction and ability to provide enough protection to allow the body assemblies to withstand vibration waves encountered during vibration at +125°F and -20°F temperature extremes. The test samples were preconditioned to the respective temperatures for a period of 24-hr minimum prior to tests.

Sample 1 was vibrated in the vertical (fig. 2), longitudinal, and transverse directions at +125°F for 2 hr, sequentially for a total duration of 6 hr.

Sample 2 was vibrated in the vertical, longitudinal, and transverse directions at -20°F for 2 hr, sequentially for a total duration of 6 hr.

Two failures were observed after completing this test series. The first was that most of the nails holding the steel corner straps of the top and bottom assemblies were loose; the other failure was that a wood support with a large knot at the center of sample 2 was broken (fig. 3).

Corrective actions were taken after evaluation of the noted failure modes as follows:

1. In regard to the loose nails, it was decided to increase the number of nails from 6 to 8 to each corner strap.

2. In regard to the wood support failure, failure was attributed to a manufacturing quality control defect; therefore, the support was replaced, and the pallet was reused for the next series of loose cargo tests.

Loose Cargo Vibration Tests

This test was run at ambient temperature with test samples 1 and 2 constrained on a vibrating platform that had a vertical double-amplitude (peak-to-peak) of 1 in. The samples were free to bounce vertically.

Samples 1 and 2 were vibrated for 2 hr each.

After the tests, it was observed that some corrugated fiberboard dust appeared at the intersection of the top and bottom assemblies of both pallets, all nails stayed in place, and no significant damage was found on the outside surface of the pallets.

Edgewise Drop Tests

For this test series, the loaded pallet was supported along its base edge by a 5-in. high block of wood. The opposite end of the pallet was raised and allowed to fall freely from heights of 12 and 24 in. onto a rigid horizontal steel surface. The test was repeated on each edge of the pallet for a total of eight drops (2 heights x 4 edges).

Test sample 1 was temperature conditioned to +125°F and dropped from 12- and 24-in. heights on each of its four pallet edges.

Test sample 2 was temperature conditioned to -20°F and dropped from the same 12- and 24-in. heights on each of its four pallet edges.

After the tests, it was observed that more corrugated fiberboard dust appeared at the intersection of the top and bottom assemblies of both pallets. However, all nails stayed in place, and no significant damage was found on the outside surface of the pallets.

Cornerwise Drop Tests

The loaded pallet was supported along its base edge on a 5-in. high block of wood. A second block of wood was placed under one corner of the same raised edge base of the pallet to raise the corner a total of 12 in. above the floor. The end of the pallet opposite the 12-in. high corner was raised and allowed to fall freely from heights of 12 and 24 in. onto a rigid horizontal steel surface. The test was repeated on two diagonally opposite corners of the pallet base.

Test sample 1 was temperature conditioned to +125°F and dropped on one corner from 12- and 24-in. heights; the test was repeated on a diametrically opposite corner for a total of four drops.

Test sample 2 was temperature conditioned to -20°F and dropped on one corner from the same 12- and 24-in. heights; the test was repeated on a diametrically opposite corner for a total of four drops.

During these tests, a noticeable amount of corrugated fiberboard dust spilled out from the intersection of the top and bottom assemblies of both pallets. Upon becoming aware of this event, a decision was made to open the containers to evaluate the damage. After removing the top assemblies, it was noticed that the corrugated partitions had been severely worn down and deformed. All body assemblies were covered by the worn-out corrugated fiberboard dust (fig. 4). Another observation was that almost no body assemblies were held in their original shipping positions (fig. 5). The test results indicated that the corrugated fiberboard materials would not only provide minimal protection but also severely contaminate the body assemblies. At this point, it was determined that using the corrugated materials for this packaging was totally unacceptable.

In order to resume the tests as soon as possible, the ARDEC carpentry shop was given a task to fabricate three sets of partitions made from quality plywood to replace the corrugated fiberboard partitions in the remaining empty pallets. The thickness of the partitions was reduced to 1/4 in., based on the suggestion from the staff in the Environmental Test Lab. A few days later, the inert body assemblies were

transferred from the two broken pallets to the two new pallets, designated as numbers 3 and 4 with new plywood partitions, and the number of body assemblies per pallet was reduced from 238 to 208. An additional weight of 54 lb was also added to cover the possible weight variation of packing. The new test gross weight became 850 lb (386 kg). The test was restarted from the loose cargo vibration test above.

Loose Cargo Vibration Tests

Samples 3 and 4 were constrained on the vibrating platform for the loose cargo vibration tests at ambient temperature with the same acceptance criteria as the loose cargo vibration test above. Sample 3 was loosely vibrated for 2 hr followed by sample 4 being loosely vibrated for 2 hr also.

After completion of these tests, the test units were examined, and the following observations were noted: all nails stayed in position; no significant damage on either pallet; no plywood particles on either pallet. Consequently, it was judged that the pallets passed the loose cargo tests.

Edgewise Drop Tests

The edgewise drop tests were conducted after the loose cargo vibration tests, after the samples were temperature conditioned (i.e., sample 3 to +125°F and sample 4 to -20°F). The acceptance criteria were the same as the edgewise drop test above.

- Sample 3, temperature conditioned at +125°F, was dropped eight times (two times each end from 12- and 24-in. heights).

- Sample 4, temperature conditioned at -20°F, was dropped eight times (two times each end from 12- and 24-in. heights).

After completion of the tests, the test units were examined and the following observations were noted: all nails stayed in position; no significant damage on either pallet; no plywood particles on either pallet. Consequently, it was judged that the pallets passed these edgewise drop tests.

Cornerwise Drop Tests

The cornerwise drop tests were conducted after the edgewise drop tests on the same samples 3 and 4 temperature conditioned to the same +125°F and -20°F. The acceptance criteria was the same as the cornerwise drop test above.

- Sample 3, temperature conditioned at +125°F, was dropped four times on two corners (two times on each corner from 12- and 24-in. heights).

- Sample 4, temperature conditioned at -20°F, was dropped four times on two corners (two times each corner from 12- and 24-in. heights).

After completion of the tests, the following observations were noted: all nails stayed in position; neither significant damage nor plywood particles were found on either pallet. Consequently, it was determined that the pallets passed these cornerwise drop tests.

Pendulum Impact Tests

To do this test, the pallet with its end touching a rigid, flat, and vertical hard wood wall was suspended by four flat nylon cables (fig. 6). Once suspended in place, the pallet load was pulled back by a chain until its center of gravity was raised to 20.5 in. from its vertically suspended position, then released by a locking mechanism to allow it to swing freely and collide with the noted wall (fig. 7). The test procedure called for two impacts against the wall at each temperature condition; orientation of the swing was along the longitudinal axis, and the temperature conditioning was +125°F and -20°F.

- Sample 3, temperature conditioned at +125°F, was tested twice; once along one end and the other along the opposite end.

- Sample 4, temperature conditioned at -20°F, was tested twice, once along one end and the other along the opposite end.

After completion of the tests, no significant damage was observed on either pallet. Consequently, it was determined that the pallets passed the pendulum impact tests.

5.9-ft Drop Tests

The 5.9-ft drop tests were conducted on five different orientations at ambient temperature conditioning. This test series requires dropped the loaded pallet from 5.9 ft height on the following surfaces:

Flat on the bottom
Flat on the top
Flat on the long side
Flat on the short side
On one corner (not a surface)

The DOT regulation states that each test unit was to be dropped once on one of the required orientations; this means that one test unit for each drop or five test

units would be needed. The loaded pallet being tested weighed 850 lb, which made it not only cumbersome to handle but also a difficult unit to evaluate. In addition, only a limited number of tests units were available. Therefore, it was decided that, after each drop, undamaged or slightly damaged test samples would be dropped again in another or next orientation in the test series. These repeated drops were to be made until either the test series was completed or the test unit failed. With this stated background, the test series was initiated. A discussion of each drop orientation follows:

- Flat on the bottom surface drop. Sample 3 was selected for this drop. After the test, it was observed that there was no significant damage nor was there any packing contents spilled. Consequently, it was determined that the pallet load passed this test.

- Flat on the top surface drop. Sample 3 was reused for this test. After the test, no significant damage nor spilled packing contents was observed; therefore, it was determined that the pallet load passed this test.

- Flat on the long side surface drop. Sample 3 was reused again for this test. Examination after the drop revealed that the top assembly received a fair amount of damage (fig. 8). Since the drop was actually the third time this pallet load was tested, the damage was neither surprising nor unexpected. Regardless of the damage, no packing contents were spilled. Therefore, it was determined that the pallet load passed this test drop, and it would not be tested further.

The pallet sample 3 was opened for additional inspection. It was noted that the egg crate partitions were still in good structural condition, and all the body assemblies stayed in their positions. No damages on the body assemblies were found.

- Flat on the short side surface drop. Sample 4 was used for this test. Examination after the test revealed that neither significant damage nor any spillage of the packing contents was observed. Therefore, it was determined that the pallet load passed this test drop.

- Corner drop. Sample 4 was reused for this test. At impact, both steel straps positioned in the longitudinal direction broke. Simultaneously, the short side supports of the top and bottom assemblies lost their reinforcement from the steel straps, making them unable to withstand the impact force created by the fallen body assemblies and pallet. They broke in the middle. In addition, the partitions were destroyed and body assemblies were allowed to spill everywhere. The pallet load failed this corner drop test.

After analyzing the failure, the number of steel straps used to reinforce the pallet load was increased from two to four in each direction; four longitudinal and four transverse straps. The body assemblies were transferred from pallet 4 to pallet 5 with new plywood partitions and eight steel straps (four in each direction).

When pallet 5 was dropped on the corner (fig. 9), the test result was encouraging. At impact, only one strap in the longitudinal direction broke, and minor damage occurred on the upper impact corner. There was no other significant damage, and there was no spill of body assemblies (fig. 10). It was determined that the pallet load with the new eight steel strap banding technique passed this corner drop test.

Stacking Test

For this test, a load equal to a stacking height of 16 ft was applied to the top of loaded pallet 5, to simulate the actual stacking load the pallets would experience during shipping and storage operations. To create this equivalent load, two steel plates that had a combined weight of 10,500 lb were used. They were placed on top of the pallet load for a period of 48 hr (fig. 11). At the end of the 48-hr period, the pallet load was examined. No deformation or damage was found. It was determined that the pallet passed this stacking test.

The pallet sample 5 was opened for final inspection. It was noted that the egg crate partitions were still in good structural condition, and all the body assemblies stayed in their positions. Also, all the body assemblies were in acceptable condition and no damage was found.

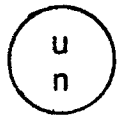
CONCLUSIONS

The test results indicated that the modified pallet had successfully passed all the packaging qualifying tests required by the Department of Defense and Department of Transportation for level C packaging. Furthermore, as all body assemblies after the tests were in acceptable condition (without damage), it was concluded that the modified pallet was capable of providing sufficient protection to 60 mm M722 white phosphorus filled body assemblies for interplant shipment and storage process within the Continental United States.

RECOMMENDATIONS

In the future, when conducting research, development, and engineering tasks that are concerned with ammunition packaging under the new Department of Transportation guidelines, the packaging technical personnel should consider the development experience described in this report for reference.

Release drawing 12937963, Packing and Marking of Interplant Shipping Pallet for white phosphorus (WP) body assemblies, M722, 60 mm, (fig. 12) to ship and store 60 mm M722 WP filled body assemblies with the following performance oriented packaging (POP) marking placed on the pallet load:

" 

4C1/X386/S/** "
USA/DOD/AYD

** The last two digits of year packed.

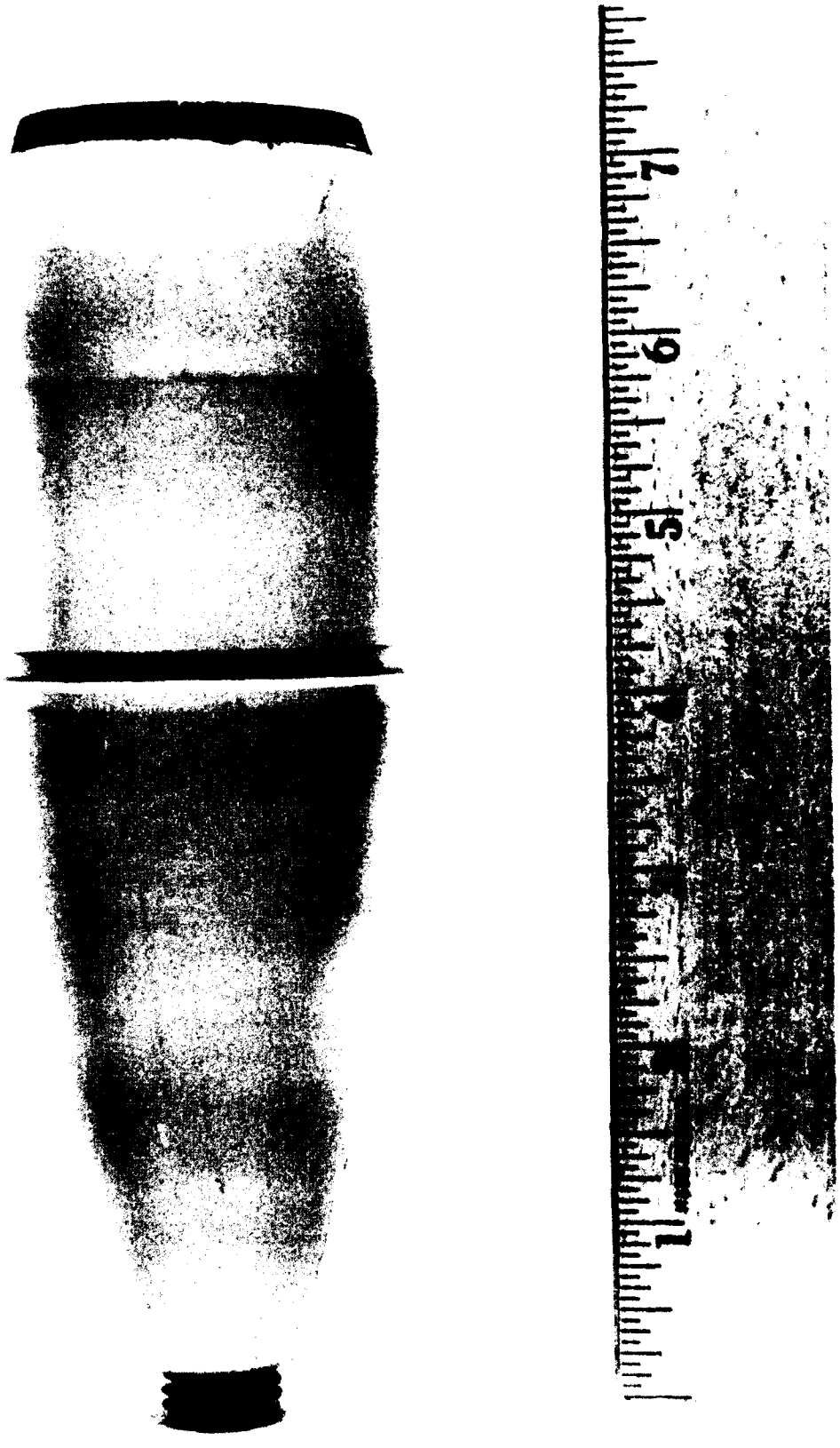


Figure 1. 60-mm mortar M722 white phosphorus filled body assembly

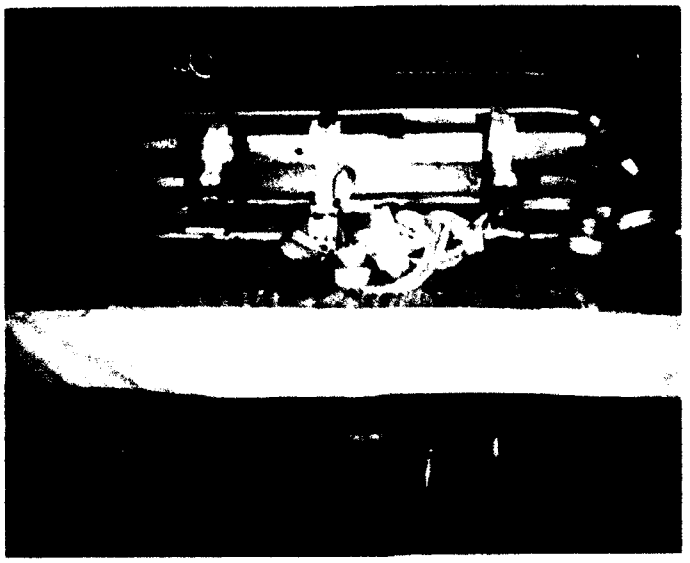


Figure 2. Secure cargo vibration test at +125°F in vertical direction

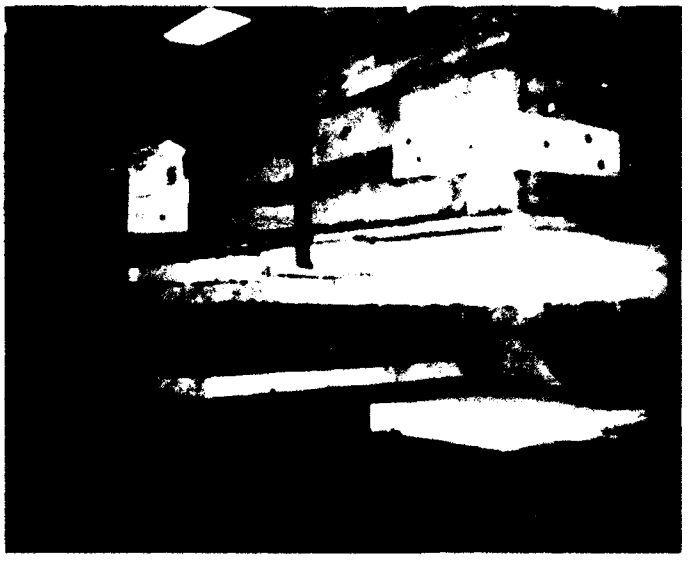


Figure 3. Wood support of sample 2 with a large knot broken after secured cargo vibration tests at -20°F

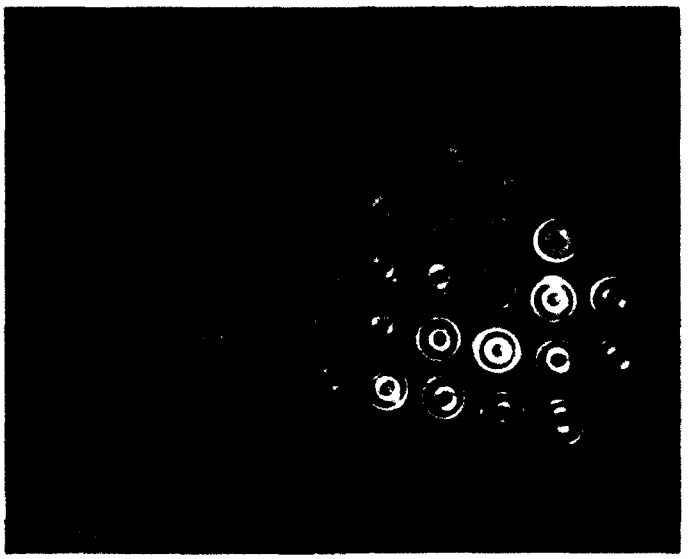


Figure 4. Corrugated partitions were severely worn down and deformed; body assemblies were contaminated by fiberboard dust

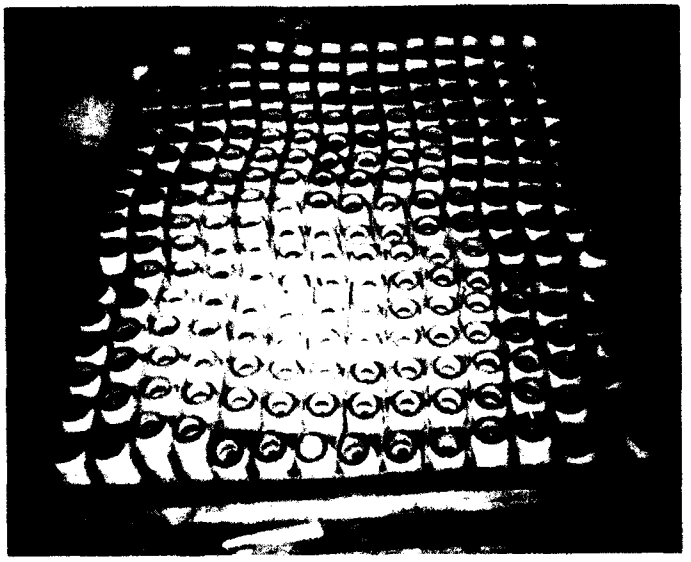


Figure 5. Body assemblies could not be held in their original shipping positions

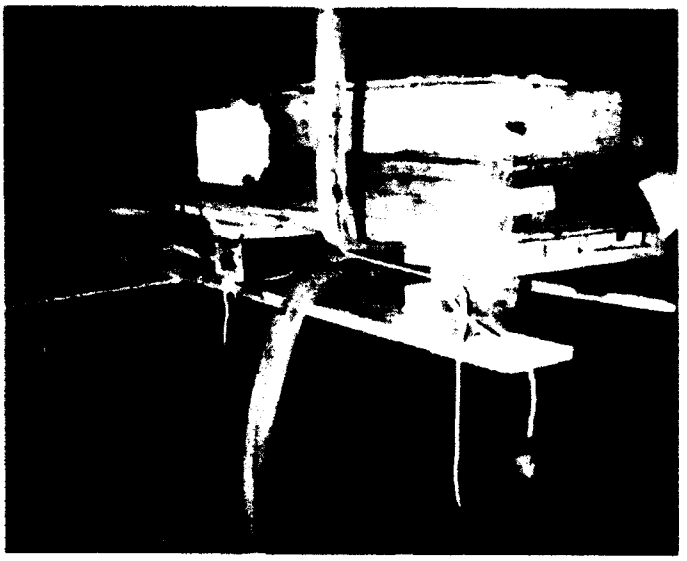


Figure 6. Pallet was suspended by flat nylon cables for pendulum impact tests

Figure 7. Pendulum impact test

Figure 8. Test sample 3 after 5.9-ft drop on the long side surface

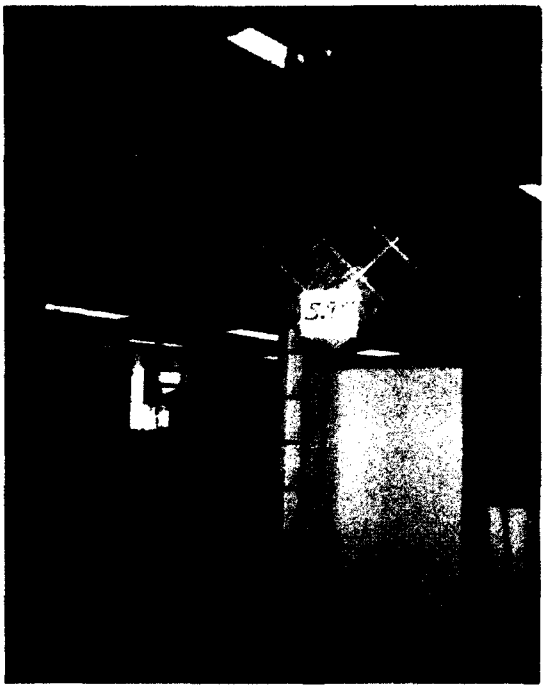


Figure 9. 5.9-ft drop on a corner

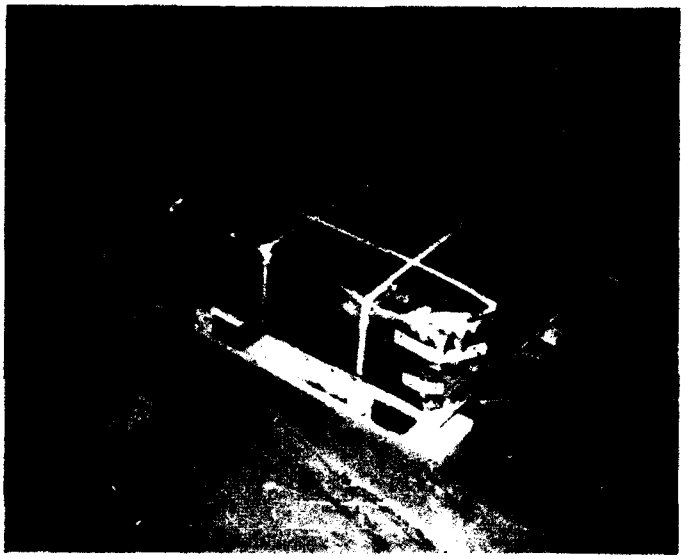


Figure 10. Pallet that received minor damage passed the 5.9-ft drop on the corner

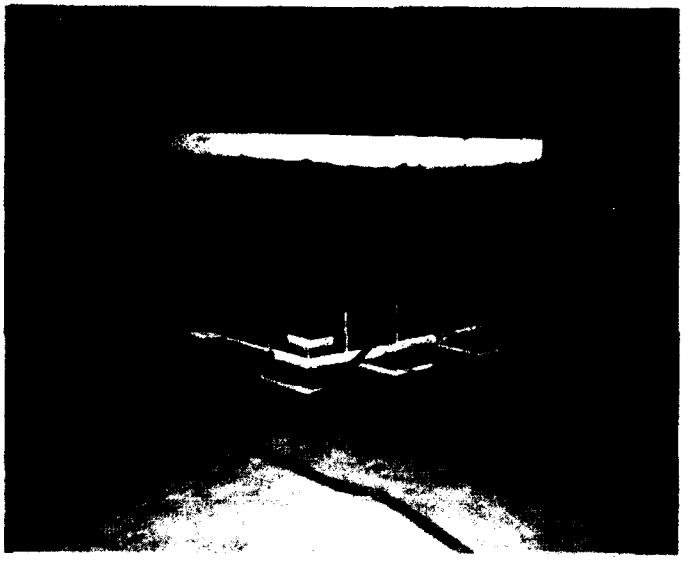


Figure 11. Stacking test

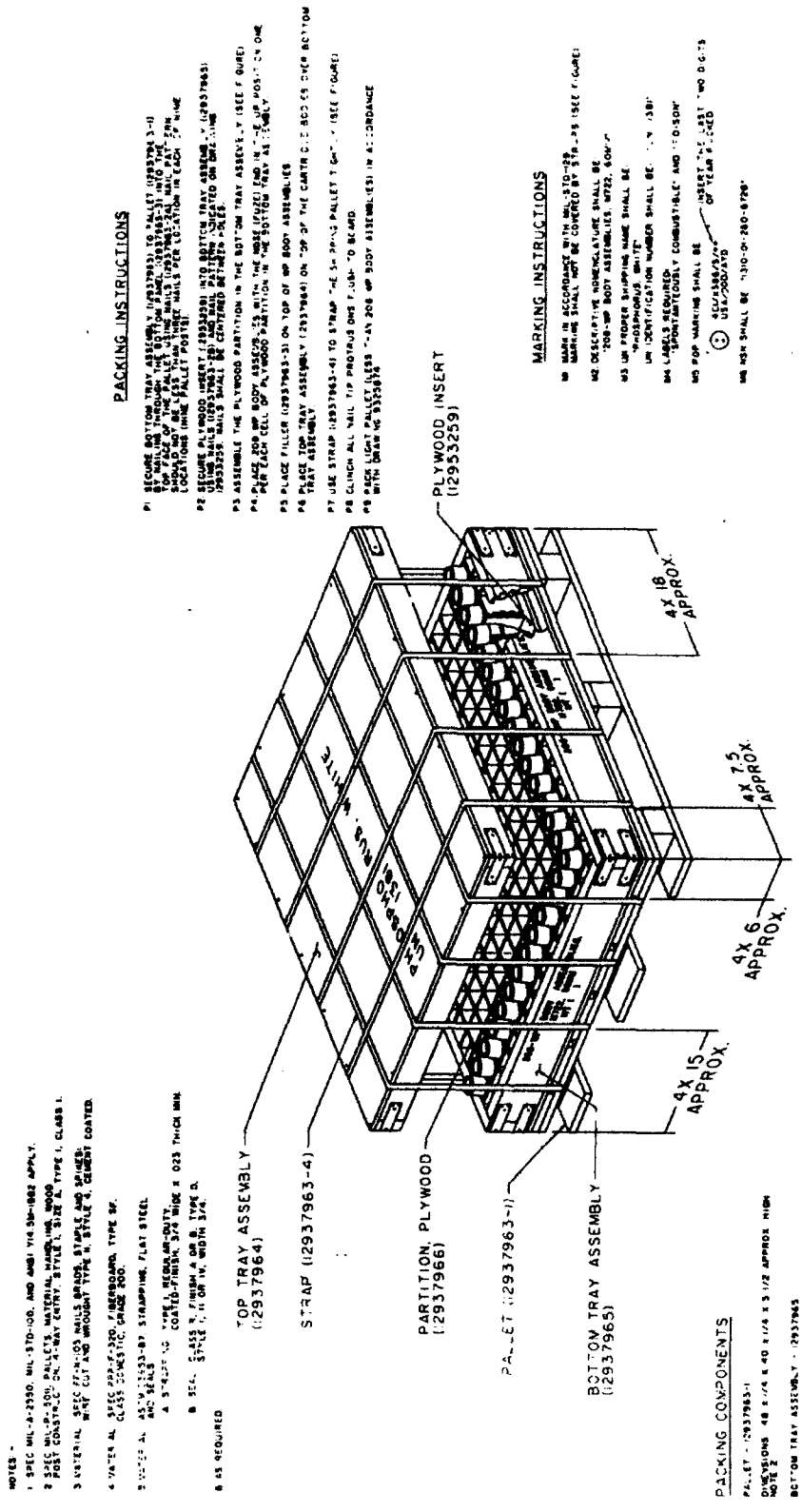


Figure 12. Shipping pallet for 60-mm mortar M722 white phosphorus filled body assemblies

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